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IRREGULARITY OF THE HEART'S ACTION IN HORSES AND ITS RELATIONSHIP TO FIBRILLATION OF THE AURICLES IN EXPERIMENT AND TO COMPLETE IRREGULARITY OF THE HUMAN HEART.

By THOMAS LEWIS.

Reprinted from "Heart."
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IRREGULARITY OF THE HEART'S ACTION IN HORSES AND ITS RELATIONSHIP TO FIBRILLATION OF THE AURICLES IN EXPERIMENT AND TO COMPLETE IRREGULARITY OF THE HUMAN HEART.

By THOMAS LEWIS.*

(*From the Cardiographic Department, University College Hospital Medical School*).

Towards the termination of the observations made upon complete irregularity of the heart's action in the human subject, a full report of which was published in *Heart* in March, 1910, it occurred to me that if I could find a similar pathological affection in any of the lower animals, it might finally settle the nature of the irregularity with which I had to deal.

My clinical observations and my experiments all pointed in one direction, and I felt confident that the disorder of the ventricular movements was in reality the outcome of fibrillation of the auricles. The discovery of a similar irregularity in one of the lower mammalia would provide an opportunity of putting the matter to a direct test, for an animal so affected might be opened and the heart inspected as it beat *in situ*.

My attention was directed especially to the domesticated animals, for they have a similar environment to man and are under observation and control. I first thought of the dog, and made a number of enquiries in regard to the pathological mechanism of the heart in this animal, but eventually abandoned the search because of the marked respiratory arrhythmia which the dog exhibits. I had no hope of obtaining the material I required from this source, if it exists, for on account of its obvious rarity and the presence of the natural arrhythmia, I could neither collect it myself, nor rely upon the observations of others in identifying the irregularity sought.

Horses became the next subjects of search. The relative frequency with which these animals are vetted, and the regularity of the heart's action in horses suggested that they might be a suitable hunting ground; and I was encouraged by the description in several veterinary text books of a rare affection of the horse's heart under the term "tumultuous action of the heart." But I should not have been successful had it not been for the great kindness of Professor Woodruff of the Royal Veterinary College, and for that of Major-General F. Smith, who was then chief of the Royal Army Veterinary Corps. While Professor Woodruff arranged that a careful

* Working under the tenure of a Beit Memorial Research Fellowship.

search should be made amongst horses attending the out-patient department at the Veterinary College, General Smith very kindly sent circulars of enquiry to the various depôts under his command. I was able to interest a number of other veterinary men, both in London and the provinces. In this manner a very large number of animals came under observation from the required point of view ; and, although the affection is of great rarity in horses, I have been fortunate enough to collect notes and observations upon five animals. These notes and observations are by no means complete. The difficulties connected with such work are considerable. It has to be carried out in places ill suited to it and observations are often hampered by the prejudice of the owner or by official restrictions. Nevertheless, the material which has been gathered seems of sufficient interest and importance to permit its publication in detail at the present time.

Horse 1. This animal was seen at Colchester through the courtesy of General Smith. It was a gelding cob of 15 hands 3½ inches. The age was nine years. The horse had come under observation seven months previously, when it showed symptoms which prevented it from working. Irregularity of the heart's action was noted ; when galloped a hundred yards the animal became acutely distressed, foaming at the mouth occurred, the breathing became laboured and eventually the animal staggered and fell. At times there was hæmorrhage from the nostrils. A large pulsation at the root of the neck and in the neck itself had been noted, and this was stated to be increased by exertion. There was rarely, if ever, any cyanosis. The arterial pulse was usually counted at 14-16 beats per minute.*

The animal was examined in its stable at Colchester on December the 4th, 1909. The pulse, which was palpable in the superficial temporal and submaxillary arteries, was feeble. Its rate lay between 20 and 50 per minute, varying very considerably from time to time. It was absolutely irregular in force and in rhythm. Sometimes a long pause was felt, sometimes a run of a few quick beats ; at other times beats of very varying lengths followed each other irregularly. The pulse rate increased markedly (from 40 to 90 beats per minute) with light exercise. At the root of the neck pulsation of a general welling character was visible and it could be followed along the external jugular veins as far as the middle of the neck. It was easily palpable with the finger, and the veins in which it occurred were obviously distended. The pulsation was synchronous with the arterial pulsation, but slightly more frequent in its incidence. The heart was auscultated and the irregularity in its characteristic form could be clearly identified. The first and second heart sounds seemed clear, no adventitious sounds were audible. There was no cyanosis, but there was dropsy. The legs were puffy and the most dependent portions of the belly pitted very readily on pressure. A great deal of time was spent in attempts to obtain

* The normal rate is 35-40 beats per minute.

graphic records of the movements, but they were only partially successful. Simultaneous records were out of the question, on account of the restiveness of the animal. A few arterial and venous curves were obtained separately.

A short strip of arterial curve taken from the superficial temporal artery is shown in Fig. 1. The rate for the six beats shown is 43, and the beats have respective lengths, in fifths of seconds, of 10, 5, 6·3, 4·7, 6·4 and 9·0. Another strip in my possession shows beats in fifths of seconds as follows :—7·5, 11·8, 6·5, 9·2, 4·2, 11·2, 6·4, 7·4, 7·8, 6·0, 4·4, 15·7, 6·2, 7·8, 7·6, 13·3 6·3, 7·7, 13·7 ; an average rate of 32 beats per minute.

Strips of the venous pulsation in the external jugulars are shown in Fig. 2, 3 and 4. The pulsation was carefully timed subjectively, and the sharp upstroke ending in a pointed peak synchronised with the arterial pulsation. At times a beat was recorded from the veins when no pulsation in the artery was felt. The tracings of the venous pulsations are of the characteristic plateau form and during the diastole, where this is long, a stasis wave is seen and there are fine oscillations upon it, (especially well seen in the long pause of Fig. 3 and 4).

The animal was shot and a post-mortem was made. The pericardium was thickened and enveloped in fat. The mitral and tricuspid valves seemed a little thickened. The muscle of the ventricles was thick and friable. There were some large patches of fibrosis in the left auricle. The lungs, abdominal viscera and arteries appeared normal. The heart was sent to Dr. Cohn of New York.

Horse 2. The following notes are abstracted from a War Office report. The animal was 16 years of age and had seen 9 years service in the South Wales Borderers. It had been under observation for some while for poor condition and wasting ; until 4 days before admission it had worked satisfactorily. It was brought to the sick lines on December the 28th, 1909, having refused its food. The pulse was counted at between 80 and 90. The temperature was 105·2° Fahr.* The respiration was hurried, 25 to the minute,† and there was evidence of pain, the animal looking continually round to the side. The horse refused food and water. Regurgitation through the jugulars was extraordinarily conspicuous, and quite apparent from the other end of the loose box in which it was stalled. On palpation it resembled an arterial pulse, so vigorous and strong was the beat. Congestion of the visible mucous membranes was present, but only slightly, and this probably by reason of the anæmic condition of the animal. Pain was manifested on manipulation of the cardiac area. Auscultation of the heart revealed a confused, irregular and excessive action of the heart.

Treatment was expectant. Mustard was applied over the ribs of the cardiac region. On the 29th the high temperature was maintained and the

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* The normal temperature of the horse is 100·4-100·9° Fahr.

† The normal respiratory rate is 8-10 per minute.

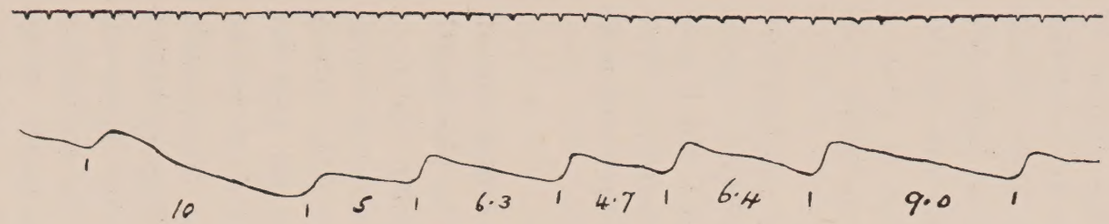

FIG. 1.

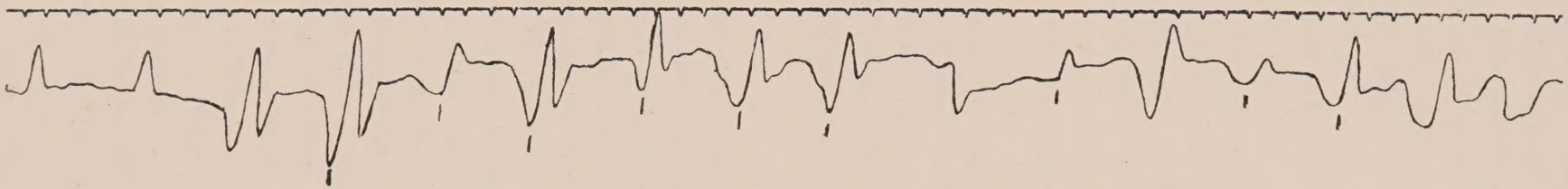

FIG. 2.

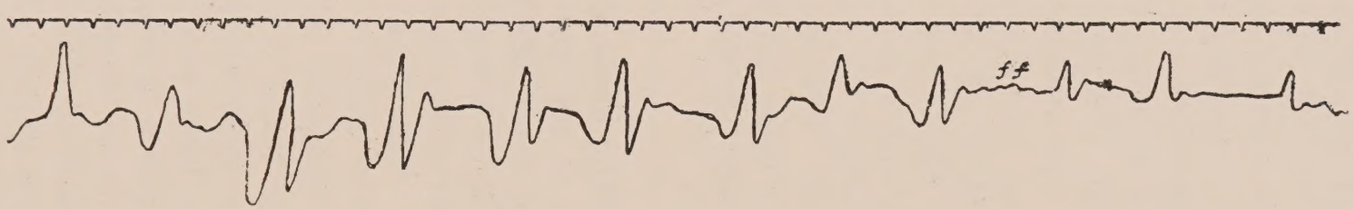

FIG. 3.

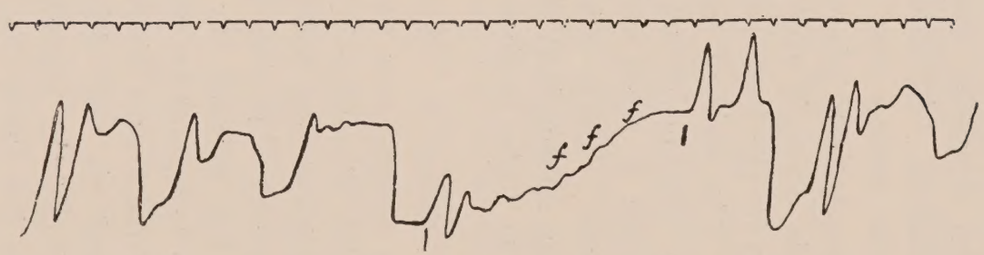

FIG. 4.

pulse was unaltered. The venous pulsation was less and the pain seemed relieved. A bran mash was eaten with some show of hunger. On the 30th the temperature fell to 102° and the pulse and respiration seemed improved ; little or no jugular pulsation was evident. Hay and mashes were taken. The heart's action is said to have been normal on this day. On the 31st the temperature rose again, but no other symptoms reappeared. From this time until the night of January the 2nd the condition was unchanged. On that night a relapse occurred, the animal refused food and water and again showed evidence of pain. There is no note of the pulse condition at this time. On the morning of the 3rd, death occurred unexpectedly. The horse was found down in its stall with the neck bent under the body. He apparently fell suddenly and with great force against the iron manger, fracturing the cranium.

At the post-mortem the skull was found fractured. The heart appeared to be abnormal. It was unhealthy in colour, its walls were hypertrophied, a few white spots were visible on the endocardium, whilst the pericardium was also thickened and slightly dropsical. The valves were unaltered. The unexpected death of the horse precluded my seeing it.

Horse 3. The observations upon this mare were made through the kindness of Sir J. Macfadyean and Professor Woodruff.

It was a cart horse, aged 15 years, 16½ hands in height. The past history was unknown. It was taken to the Veterinary College on account of breathlessness and staggering occasioned for some months by exertion.

I saw this horse on a number of occasions in January, 1910. The pulse was feeble and continuously and completely irregular ; the rate was from 40-160 per minute. The heart sounds were clear ; there were no murmurs. Little or no venous pulsation was visible in the neck while the animal stood in its stall, but it became prominent, and the rate of the heart beat increased, when it trotted a few hundred yards. The exertion also produced conspicuous dyspnœa.

Upon February the 12th, 1910, the horse was transported to some stables in the neighbourhood of University College Hospital Medical School and the stall was connected to the galvanometer. Curves were obtained by wrapping large pieces of cotton wool, soaked in saline, around metal electrodes and fastening these to the limbs or chest wall. The lead first adopted was from the right axilla to the left groin ; curves were obtained which are exemplified in the third strip of Fig. 5. The curve may be compared with that taken from a horse by Einthoven (and published as Fig. 203 in Ellenberger and Scheunert's "Lehrbuch der vergleichenden Physiologie der Haussäugetiere," Berlin, 1910). Take first the ventricular complexes marked *R*, *S* and *T* ; these portions of the curves are almost precisely the same as the corresponding phases shown in Einthoven's curve of the normal horse. They are sufficient to show that the ventricular beats in the abnormal curve are all of supraventricular origin. In Einthoven's curve each

ventricular contraction is preceded by an auricular representative, *P*, which is as prominent as the *T* shown in this strip. All trace of such variation is absent in the present instance, clearly pointing to an absence of co-ordinate and presystolic contraction of the auricle. The beats of Fig. 5 (strip *III*) are irregularly spaced; they lie at distances of 2·7, 2·9, 3·7 and 4·7 fifths of a second apart. The irregularity is of the characteristic form exhibited by a fibrillating auricle. The first two strips have a larger excursion. They were taken by applying the right forelimb electrode to the epigastrum, the left hindlimb electrode to the breast beneath the root of the neck. Compared with the third strip they are consequently inverted. These curves show the same summits *R*, *S* and *T*, but again no signs of co-ordinate auricular contraction. The rate is very variable. The irregularity in spacing is extreme. The heights of the opening variations of systole (notably *S*) are not proportionate to the pauses which precede the corresponding beats. These features are one and all characteristic of experimental fibrillation and complete irregularity of the human heart. There remains but a single feature and that is the oscillation, which is so typical in many experimental and clinical instances and which is due to the fibrillating auricle. It is obscurely seen in several places in these curves (and is marked *f*, *f*).

The pauses from beat to beat in a succession of 8 strips are tabulated and are given in the accompanying table. The successive beats read in columns from above downwards.

PULSE BEATS IN ONE-FIFTH SECONDS IN 8 STRIPS.

AS CALCULATED FROM ELECTRIC CURVES.

3·1	4·1	3·3	2·6	2·2	4·0	3·5	3·0
3·3	3·4	3·4	4·8	2·0	2·4	3·3	3·0
3·2	4·6	4·0	2·8	1·8	4·9	2·5	3·2
3·3	2·7	2·7	2·9	1·7	3·4	3·0	3·7
2·3	4·8	2·8	2·7	1·7	3·1	3·6	2·6
3·8	3·1	3·7	4·0	2·1	3·8	3·4	2·5
3·4	3·2	4·6		2·0	2·7	2·7	3·7
2·1	3·0			2·7	4·5	2·9	4·9
2·0	2·4			2·2	3·1	3·1	3·5
3·2				1·8	2·5	3·0	4·0
3·4				1·7	2·3	3·9	5·6
4·8				1·9	2·2	2.6	4·3
5·3				1·7	3·6	3·0	4·6
2·7				2·1	4·1	3·5	3·6
				2·4	3.1	3·5	2·7
				2·3	2·5	4.7	4·6
				2·6	2·4	5·4	4·5
				2·0	3·1	4·7	3·1
				1·6	3·2	3·6	
				1·7	3·8	5·7	
				3·6	2·6	3·2	
				2·0	2·3	2·4	
				1·7	2·0	4·3	
					3·6	3·0	
					2·7	2·9	
					4·2	3·7	
					3·6	3·6	
						3·9	
						3·2	
						4·0	

On February the 19th the horse was killed by a shot in the head, the trachea was immediately opened and artificial respiration was established. The chest was opened through an incision in the right chest wall by sawing through a rib. Unhappily, during the removal of the rib, the ventricle was damaged and considerable hæmorrhage occurred. There was, nevertheless, sufficient time for certain observations. The ventricle beat rapidly and irregularly, while the auricle seemed to be standing still. On catching hold of the ventricle and moving it, so as to obtain a closer view of the auricle, the former passed into fibrillation. A closer inspection of the right auricle now revealed the presence of a fine fibrillary movement in its walls. The movement was watched for some minutes, in fact till no visible contractions could be made out in either ventricle or auricle.

As a result of these observations I am able to state that in a horse which presented the characteristic irregularity, the ventricular beat was co-ordinate and of supraventricular origin, and further that the co-ordinate contraction in the auricle was in abeyance. I am unable to state that while the ventricle was beating co-ordinately the auricle was seen to be in fibrillation. But it was not contracting co-ordinately while the ventricle was beating in this fashion and it was seen to be fibrillating within a few seconds of the onset of ventricular fibrillation. We know quite definitely that fibrillation is not transmitted from ventricle to auricle, and we therefore have strong presumptive evidence that the auricle was fibrillating throughout. That the mechanism of the heart was not altered by the cerebral death of the horse is clearly shown by the continued irregular ventricular action. There is but a single source of error; it is possible that the same application of the hand and movement which induced fibrillation in the ventricle also induced fibrillation in the auricle, which was previously paralysed. But such an occurrence is in the highest degree improbable.

The heart was preserved. Its weight was 5,440 grammes.* It was sent to Dr. Cohn of New York. There was some dropsy of the subcutaneous tissues; the arteries and other organs seemed normal.

Horse 4. An old gelding of about 15 hands, the exact age and history of which was uncertain, was brought to University College Medical School from the Veterinary College on February the 18th, 1910. It was examined in the street. The animal was in a distressed condition. Dyspnœa was marked, there was some dropsy of the legs and abdominal parietes. It presented violent pulsation of the whole neck, which reached as high as the ears. It was obviously venous, and, so far as could be ascertained, systolic in time. The pulsation and the heart's sounds were extremely rapid, averaging 150 beats per minute; the several beats followed each other in the most confused and irregular manner. There were no murmurs.

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* The heart weight for medium sized horses is given at 3 to 3·5 kilo. by veterinary text books.

Further observations were not possible ; and I was unable to purchase the animal or make any further investigation of it.

Horse 5. This horse was a gelding, aged 16, in height 15½ hands. It was seen through the kindness of General Smith and Colonel L. Blenkinsop of Salisbury.

The symptoms had been present for 7 months. It had been under observation for 7 years, and was not known to have suffered from strangles or any other illness. The symptomatology consisted of very irregular and tumultuous action of the heart, marked breathlessness, epistaxis, faltering and occasionally falling, upon moderate exertion.

The horse was examined on Bulford Plain on June the 25th, 1910. The heart was absolutely irregular, long pauses of 2 seconds were frequent and short runs of rapid beats were noted from time to time. The rate was from 40 to 60 beats per minute, while resting. Upon exertion the rate showed increase, and a welling pulsation, not marked but distinct, appeared at the root of the neck. Breathlessness was fairly conspicuous after the animal had cantered a few times round a small paddock. The heart sounds were clear, there were no murmurs. The heart beats were more numerous than the arterial pulsations.

The horse was thrown in a covered yard and was chloroformed. It was then shot in the head, in compliance with the regulations, and the windpipe was opened. A good deal of blood poured from the trachea ; the shot had broken the base of the skull. As a consequence, artificial respiration was not free. The chest was opened by an incision on the right side and the removal of two ribs, and an excellent view of the beating heart was obtained. The ventricular movements were forcible and the spacing of the beats corresponded with what had been heard at the previous examination. For the horse they were rapid, and the irregularity was extreme. The ventricle showed no distension. At first no intrinsic movements could be seen in the auricle, it appeared to lie still except for the tugging transmitted from the ventricle. There was certainly no general shortening of its fibres. Closer inspection of the musculature revealed the presence of fibrillary movements. The epicardium covering the right auricle in the horse is comparatively thick and opaque and fibrillary movements are not readily seen in the underlying muscle. Close inspection of the ridges and, more especially, attention to the light reflections on its surface, particularly in the neighbourhood of the appendix, were conclusive. The independent movements of the several light reflections and the activity of the tissues generally was well displayed and was demonstrated to and recognised by the bystanders, including Colonel Blenkinsop. They were watched for several minutes, the ventricle continuing its active co-ordinate but irregular movements during the whole of this time. A hand was then placed under the ventricle, which was commencing to dilate, and in lifting it out of the pericardium it fibrillated. The auricle continued to fibrillate as before ; the two chambers were watched until all movements ceased in them.

The heart was removed, preserved and sent with the other specimens to Dr. Cohn. It weighed 4,335 grammes. The muscle was dark and friable. The pericardium and arteries seemed normal. The other organs presented little or no change.

Horse 6. While at Bulford Camp, I was shown another horse, stalled in the sick lines, by Colonel Blenkinsop. It was an old horse, suffering from chronic arthritic trouble. The heart beat at a normal rate, at or about 37 per minute. The beats followed each other perfectly regularly for about 10 or 15 cycles ; a premature beat was then audible and it was followed after a prolonged pause by a further sequence of quite regular beats at the previous rate.

The irregularity obviously belongs to a distinct category ; it corresponds to the single interruptions of a regular rhythm by pathological impulses in the human subject.

Discussion.

The foregoing observations are sufficient to establish several facts. The horse suffers on rare occasions from irregularity of the heart's action, and the irregularity may be due to the presence of isolated premature contractions (*Horse 6*), or to a high grade of disorder in which the irregularity is complete. The completeness of the last irregularity has been observed in four separate animals and in two of these (*Horses 1* and *5*) graphic records have been obtained, confirming the subjective findings. The heart rate is variable but is generally increased. In the normal horse the rate lies between 35 and 40 per minute. When the gross irregularity is present the rate of the pulse may be decreased, presumably as a result of dropped beats ; the heart rate on the other hand may accelerate to rates of 160 per minute for brief or long periods. The electrocardiograms (*Horse 3*) show that the irregularly beating ventricle is governed by impulses which descend to it through the auriculo-ventricular bundle and its branches ; in every other way they correspond to the curves obtained in complete heart irregularity as it is observed in the human subject, and to the curves of auricular fibrillation as observed in experiment.

In two animals, from one of which graphic records were obtained, an inspection of the heart, beating *in situ*, revealed, first an irregularly beating ventricle and secondly a pulsationless auricle. In both, fibrillation of the auricle was witnessed. In the first of these observations (*Horse 3*) damage was done to the ventricle in opening the chest and there may be some doubt as to whether the auricular fibrillation did not follow upon this damage. This doubt is removed, for a precisely similar phenomenon was seen in the second observation (*Horse 5*), and in this instance no such damage occurred. The heart, at the inspection of it, was beating actively and was in good condition.

The presence of the same form of mechanism before and after the cerebral death of the animals and the resection of the ribs can scarcely be doubted, for the ventricular action remained constant throughout the whole of the preliminary procedures in both instances.

We are left with the conclusion that chronic fibrillation of the auricle is a pathological fact in horses, and that it is associated with an action of the heart which is in every way similar to that known as complete irregularity of the heart in man and to the irregularity which supervenes when the auricles are forced into fibrillation in the dog or cat.

Taking this evidence and that which has been previously recorded into consideration, the final conclusion that the three ventricular irregularities, namely, that which is found in the horse, that which is observed in man and that which is induced in the dog or cat, are one and the same seems indisputable. They are all dependent upon one underlying factor, namely incoordinate or fibrillary contraction of the auricular tissues.

It is of interest to observe that in none of the five instances of auricular fibrillation in the horse was there any definite evidence of valvular lesion. It is known that in many of the human patients the valve segments are intact. The underlying mischief must be sought in the musculature itself. It is with this in mind and with a view to the eventual comparison of the human and equine material that I have asked my friend Dr. Cohn, whose knowledge of these muscle changes is so full, to undertake a detailed examination of the hearts which I have been able to obtain.*

Conclusions.

1. Horses are on rare occasions the subjects of two forms of irregularity of the heart. One of these consists of isolated premature contractions. The other is a complete irregularity.

2. The complete irregularity which occurs in the action of the ventricle of horses may be seen, from inspection of the heart as it beats *in situ*, to be associated with fibrillation of the auricles ; a condition which must therefore be held as a proved pathological condition in these animals.

3. Fibrillation of the auricles in horses gives rise to a condition in which the symptomatology, and especially the graphic records, are identical in all their classical features, with a condition known as complete irregularity of the heart in man.

4. Complete irregularity of the heart in man is unquestionably associated with fibrillation of the auricles.

5. Fibrillation of the auricles in horses is usually unaccompanied by valvular lesions. It is accompanied by grave circulatory troubles which may be classed under the general term of heart failure.

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* Brief reports of these findings have been published in *Heart*, 1909-10, 1, 306, in the *Verhandl. d. deutsch. pathol. Gesellsch.*, 1910, 112 ; and in the *Mechanism of the Heart-beat*, *London*, 1911,

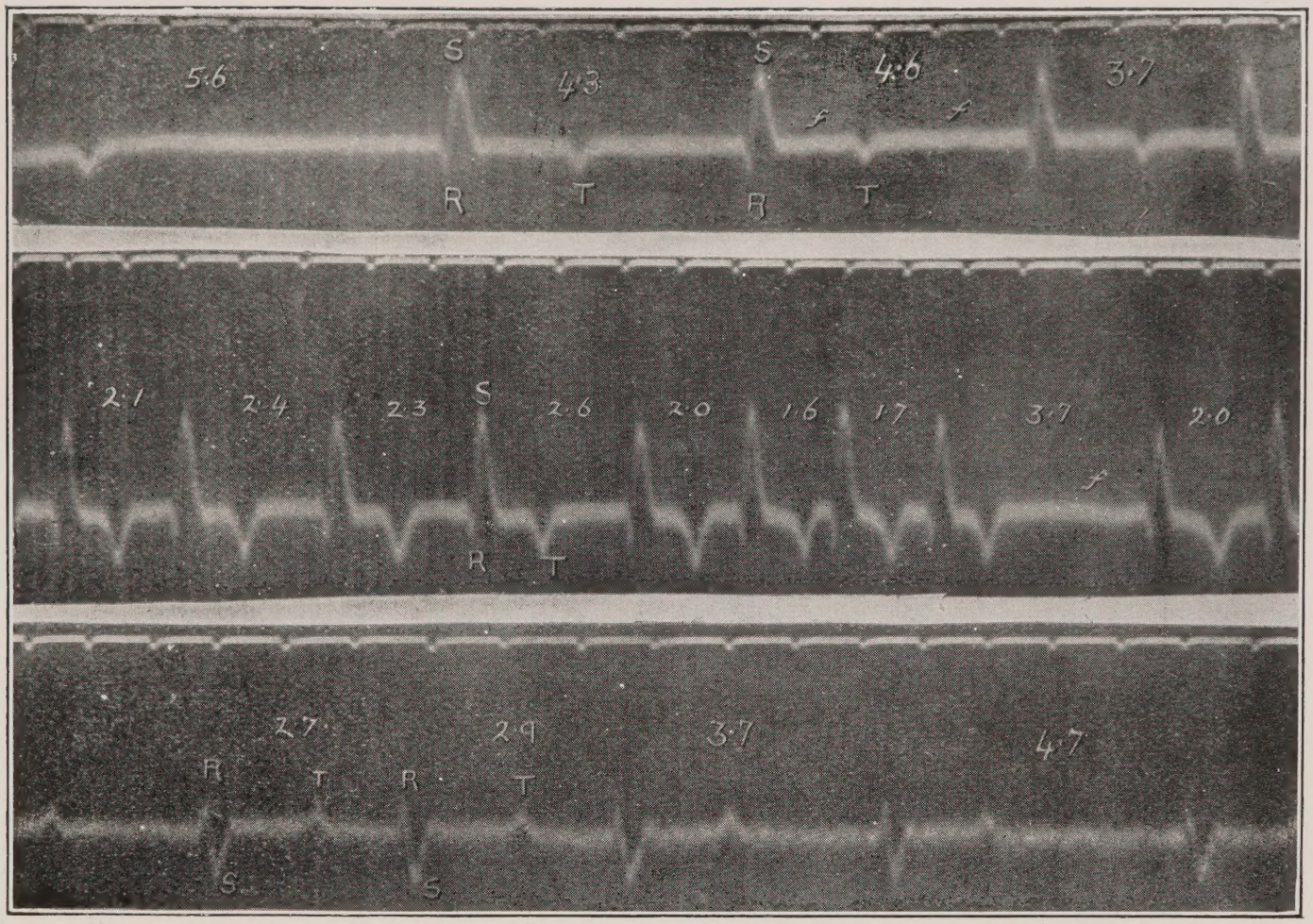

Fig. 5. ($\times \frac{5}{8\ 5}$). Three electrocardiograms from the third horse, the last strip is from the right fore-limb and left hind-limb. Complete irregularity of the heart is present, each heart cycle is represented by *R*, a large *S* and a *T* variation; there is no sign of *P*. There are traces of oscillations in the longest diastolic periods shown.

The first two strips were taken from the epigastrium and centre of the breast in front; (they are consequently inverted). They show the same characters as those exhibited by the third strip. The irregularity is of high grade, the heart rate at times exceeds 150 per minute (normal 35-40). Oscillations are most distinct in the first strip. *P* is completely absent.

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